Appendix I

Bayesian Surplus Production Documentation

See text for explanation of variables. WinBugs program statements used to produce Bayesian surplus production estimates are shown below for northern and southern management regions.

```
*************************************************
Northern Goosefish
Bayesian State-Space Implementation
of Pella-Thomlinson Production Model

#  Jon Brodziak, NEFSC, October 2004
#####################################################################
model NGOOSE
{

# Prior distributions
####################################################

# Gamma prior for shape parameter, M
# as 1+gamma(2,2) with mean=1 and var=1/2
#(1)##################################################
x ~ dgamma(2,2)
M <- x+1

# Lognormal prior for carrying capacity parameter, K
#(2)##################################################
# Uniform prior for K from 10 kt to 10000 kt
K ~ dunif(10,10000)

# Beta prior for intrinsic growth rate parameter, r
# with mean=0.5 and CV=20%
#(3)##################################################
 y ~ dbeta(12.0,12.0)
r <- 0.1+(0.9*y)

# Gamma priors for survey catchability coefficients
# within interval (0.0001,10)
#(4)##################################################
iqFALL ~ dgamma(0.001,0.001)I(0.1,10000)
qFALL <- 1/iqFALL

# Gamma prior for process error variance, sigma2
#(6)##################################################
isigma2 ~ dgamma(a0,b0)
sigma2 <- 1/isigma2

# Gamma priors for observation error variances, tau2
#(7)##################################################
itau2FALL   ~ dgamma(c0FALL,d0FALL)
tau2FALL   <- 1/itau2FALL

# Lognormal priors for time series of proportions of K, p[]
#(8)##################################################
# Time series starts in 1964 and ends in 2003
Pmean[1] <- 0
P[1] ~ dlnorm(Pmean[1],isigma2) I(0.001,4)
dlow[1] <- dlowpre*NomCatch[1]
dup[1] <- duppre*NomCatch[1]
Catch[1] ~ dunif(dlow[1],dup[1])

# Low precision catch during 1964-1992
for (i in 2:29) {
   Pmean[i] <- log(max(P[i-1]+r*P[i-1]*(1-pow(P[i-1],M-1.0))-Catch[i-1]/K,0.001))
```

```
   P[i]  ~ dlnorm(Pmean[i],isigma2)I(0.001,4)
   dlow[i] <- dlowpre*NomCatch[i]
   dup[i] <- duppre*NomCatch[i]
   Catch[i] ~ dunif(dlow[i],dup[i])
   }

# High precision catch during 1993-2003
for (i in 30:N) {
   Pmean[i] <- log(max(P[i-1]+r*P[i-1]*(1-pow(P[i-1],M-1.0))-Catch[i-1]/K,0.001))
   P[i]  ~ dlnorm(Pmean[i],isigma2)I(0.001,4)
   dlow[i] <- dlowcur*NomCatch[i]
   dup[i] <- dupcur*NomCatch[i]
   Catch[i] ~ dunif(dlow[i],dup[i])
   }

# Lognormal likelihood for cooperative survey biomass in 2001
# based on observed biomass (Bobs2001) and efficiency (eff)
#(9)################################################
PREDmean2001 <- log(K*P[38])
SurveyB2001 <- Bobs2001/eff
SurveyB2001 ~ dlnorm(PREDmean2001, SurveyPrec2001)

# Lognormal likelihood for observed survey indices
#(10)################################################
# FALL SURVEY LIKELIHOOD 1964-2003 P[1:40]
for (i in 1:NFALL) {
    ImeanFALL[i] <- log(qFALL*K*P[i])
    IFALL[i] ~ dlnorm(ImeanFALL[i],itau2FALL)
    RESIDFALL[i] <- IFALL[i] - qFALL*K*P[i]
             }

# Compute exploitation rate and biomass time series
#(11)################################################
# 1964-2003 P[1:40]
for (i in 1:N) {
    B[i] <- P[i]*K
    H[i] <- Catch[i]/B[i]
   }
P2004 <- max(P[N]+r*P[N]*(1-pow(P[N],M-1.0))-Catch[N]/K,0.001)
B2004 <- P2004*K

# Lognormal likelihood for cooperative survey biomass in 2004
# based on observed biomass (Bobs2004) and efficiency (eff)
#(11.5)################################################
PREDmean2004 <- log(B2004)
SurveyB2004 <- Bobs2004/eff
SurveyB2004 ~ dlnorm(PREDmean2004, SurveyPrec2004)

# Compute reference points
#(12)################################################
BMSP <- K*pow((1.0/M),(1.0/(M-1.0)))
PMSP <- BMSP/K
MSP <- r*BMSP*(1.0-(1.0/M))
HMSP <- r*(1.0-(1.0/M))
INDEXMSPFALL <- qFALL*BMSP
BMSPRATIO <- B[N]/BMSP
BLIMITRATIO <- 2*B[N]/BMSP
HRATIO <- H[N]/HMSP

# END OF CODE
####################################################
}
Data
# Vector C() is total catch in thousand mt, 1964-2003
# Catch is GC for 1964-1981, WO+NC for 1982-1995, WO+D for 1996-2003
# Vector IFALL() is autumn kg/tow index, 1964-2003 (NFALL = 40 yrs)
# Sigma is state equation error with parameters a0,b0
# TauFALL is autumn observation error with parameters c0FALL,d0FALL
# Observed cooperative survey swept-area biomass set using
```

```
# intermediate efficiency and inclinometer distances Table C35, part C).
#(13)########################################################
list(
NomCatch=c(0.0495,0.0407,0.3289,0.594,0.4939,0.264,0.2189,0.2343,0.4807,
0.7788,1.32,2.0647,2.4816,3.4837,4.3736,4.4748,3.9853,3.4881,
4.246,4.2339,4.6222,5.0776,4.7597,5.456,5.5726,7.0301,6.3822,
6.2623,7.6153,11.7095,12.045,13.2352,12.626,11.07,8.058,9.915,11.544,
17.78497751,16.8105705,17.89984931),
IFALL=c(1.71235,2.50877,3.26621,1.28262,2.03626,3.7046,2.23697,2.9139,1.40358,3.11401,2.06265,1.71083,3.38701,5.5675,5.10086,5.1329,
4.45818,1.98444,0.935873,1.61742,3.01021,1.44087,2.35346,0.873207,1.52452,1.38425,1.00069,1.23533,1.104,1.04435,0.973433,1.71112,1.07
1,0.669,0.974,0.825,2.495,2.048,2.103,1.925),
N=40,NFALL=40,
a0=4.0,b0=0.01,
c0FALL=2.0,d0FALL=0.01,
dlowpre=0.90,
duppre=1.10,
dlowcur=0.99,
dupcur=1.01,
Bobs2001=68.680, eff=1.0, SurveyPrec2001=10.0,
Bobs2004=51.766, eff=1.0, SurveyPrec2004=1.0)
# Use a highly precise hammer to nail down trend

# Bobserved=68.680, eff=1.0, SurveyPrec=0.021)
# Assume a CV of 10% on survey biomass to set SurveyPrec
# 0.1*68.68 = 13.74 = STDEV, PRECISION = 1/VARIANCE = 1/47.17 = 0.021

Inits
# P[1:40] from 1964-2003
#(14)########################################################
# Initial Condition 1
list(P=c(0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.75,
0.75,0.75,0.5,0.5,0.5,0.4,0.4,0.4,0.3,0.3,0.3,0.2,0.2,0.2,0.2,0.2,0.2,0.2,
0.2,0.2,0.3,0.3,0.3,0.4,0.4),
Catch=c(0.0495,0.0407,0.3289,0.594,0.4939,0.264,0.2189,0.2343,0.4807,
0.7788,1.32,2.0647,2.4816,3.4837,4.3736,4.4748,3.9853,3.4881,
4.246,4.2339,4.6222,5.0776,4.7597,5.456,5.5726,7.0301,6.3822,
6.2623,7.6153,11.7095,12.045,13.2352,12.626,11.07,8.058,9.915,11.544,
17.78497751,16.8105705,17.89984931),
K=150,
x=1.1,
y=0.5,
iqFALL=100,
isigma2=100,
itau2FALL=100)
# Initial Condition 2
list(P=c(0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.75,
0.75,0.75,0.5,0.5,0.5,0.4,0.4,0.4,0.3,0.3,0.3,0.2,0.2,0.2,0.2,0.2,0.2,0.2,
0.2,0.2,0.3,0.3,0.3,0.4,0.4),
Catch=c(0.0495,0.0407,0.3289,0.594,0.4939,0.264,0.2189,0.2343,0.4807,
0.7788,1.32,2.0647,2.4816,3.4837,4.3736,4.4748,3.9853,3.4881,
4.246,4.2339,4.6222,5.0776,4.7597,5.456,5.5726,7.0301,6.3822,
6.2623,7.6153,11.7095,12.045,13.2352,12.626,11.07,8.058,9.915,11.544,
17.78497751,16.8105705,17.89984931),
K=100,
x=1.1,
y=0.5,
iqFALL=100,
isigma2=100,
itau2FALL=100)
```

Southern Goosefish
Bayesian State-Space Implementation
of Pella-Thomlinson Production Model

```
#  Jon Brodziak, NEFSC, October 2004
###################################################################

model SGOOSE
{

# Prior distributions
###################################################

# Gamma prior for shape parameter, M
# as 1+gamma(2,2) with mean=1 and var=1/2
#(1)##################################################
x~dgamma(2,2)
M <- 1+x

# Lognormal prior for carrying capacity parameter, K
#(2)##################################################
# Uniform prior for K from 10 kt to 10000 kt
K ~ dunif(10,10000)

# Beta prior for intrinsic growth rate parameter, r
# with mean=0.5 and CV=20%
#(3)##################################################
 y ~ dbeta(12.0,12.0)
r <- 0.1+(0.9*y)

# Gamma priors for survey catchability coefficients
# within interval (0.0001,10)
#(4)##################################################
iqFALL ~ dgamma(0.001,0.001)I(0.1,10000)
qFALL <- 1/iqFALL
iqSCALLOP ~ dgamma(0.001,0.001)I(0.1,10000)
qSCALLOP <- 1/iqSCALLOP

# Gamma prior for process error variance, sigma2
#(6)##################################################
isigma2 ~ dgamma(a0,b0)
sigma2 <- 1/isigma2

# Gamma priors for observation error variances, tau2
#(7)##################################################
itau2FALL   ~ dgamma(c0FALL,d0FALL)
tau2FALL   <- 1/itau2FALL
itau2SCALLOP   ~ dgamma(c0SCALLOP,d0SCALLOP)
tau2SCALLOP   <- 1/itau2SCALLOP

# Lognormal priors for time series of proportions of K, p[]
#(8)##################################################
# Time series starts in 1964 and ends in 2003
Pmean[1] <- 0
P[1] ~ dlnorm(Pmean[1],isigma2) I(0.001,4)
dlow[1] <- dlowpre*NomCatch[1]
dup[1] <- duppre*NomCatch[1]
Catch[1] ~ dunif(dlow[1],dup[1])

# Low precision catch during 1964-1992
for (i in 2:29) {
   Pmean[i] <- log(max(P[i-1]+r*P[i-1]*(1-pow(P[i-1],M-1.0))-Catch[i-1]/K,0.001))
   P[i]  ~ dlnorm(Pmean[i],isigma2)I(0.001,4)
   dlow[i] <- dlowpre*NomCatch[i]
   dup[i] <- duppre*NomCatch[i]
   Catch[i] ~ dunif(dlow[i],dup[i])
   }
```

```
# High precision catch during 1993-2003
for (i in 30:N) {
   Pmean[i] <- log(max(P[i-1]+r*P[i-1]*(1-pow(P[i-1],M-1.0))-Catch[i-1]/K,0.001))
   P[i]  ~ dlnorm(Pmean[i],isigma2)I(0.001,4)
   dlow[i] <- dlowcur*NomCatch[i]
   dup[i] <- dupcur*NomCatch[i]
   Catch[i] ~ dunif(dlow[i],dup[i])
   }

# Lognormal likelihood for cooperative survey biomass in 2001
# based on observed biomass (Bobs2001) and efficiency (eff)
#(9)################################################
PREDmean2001 <- log(K*P[38])
SurveyB2001 <- Bobs2001/eff
SurveyB2001 ~ dlnorm(PREDmean2001, SurveyPrec2001)


# Lognormal likelihood for observed survey indices
#(10)################################################
# FALL SURVEY LIKELIHOOD 1964-2003 P[1:40]
for (i in 1:NFALL) {
    ImeanFALL[i] <- log(qFALL*K*P[i])
    IFALL[i] ~ dlnorm(ImeanFALL[i],itau2FALL)
    RESIDFALL[i] <- IFALL[i] - qFALL*K*P[i]
              }
# SCALLOP SURVEY LIKELIHOOD 1984-2003 P[20:40]
for (i in 1:NSCALLOP) {
    ImeanSCALLOP[i] <- log(qSCALLOP*K*P[i+20])
    ISCALLOP[i] ~ dlnorm(ImeanSCALLOP[i],itau2SCALLOP)
    RESIDSCALLOP[i] <- ISCALLOP[i] - qSCALLOP*K*P[i+20]
   }

# Compute exploitation rate and biomass time series
#(11)################################################
# 1964-2003 P[1:40]
for (i in 1:N) {
    B[i] <- P[i]*K
    H[i] <- Catch[i]/B[i]
   }
P2004 <- max(P[N]+r*P[N]*(1-pow(P[N],M-1.0))-Catch[N]/K,0.001)
B2004 <- P2004*K

# Lognormal likelihood for cooperative survey biomass in 2004
# based on observed biomass (Bobs2004) and efficiency (eff)
#(11.5)################################################
PREDmean2004 <- log(B2004)
SurveyB2004 <- Bobs2004/eff
SurveyB2004 ~ dlnorm(PREDmean2004, SurveyPrec2004)

# Compute reference points
#(12)################################################
BMSP <- K*pow((1.0/M),(1.0/(M-1.0)))
PMSP <- BMSP/K
MSP <- r*BMSP*(1.0-(1.0/M))
HMSP <- r*(1.0-(1.0/M))
INDEXMSPFALL <- qFALL*BMSP
INDEXMSPSCALLOP <- qSCALLOP*BMSP
BMSPRATIO <- B[N]/BMSP
BLIMITRATIO <- 2*B[N]/BMSP
HRATIO <- H[N]/HMSP
# END OF CODE
####################################################
}

Data
# Vector C() is total catch in k mt, 1964-2003
# Vector IFALL() is autumn kg/tow index, 1964-2003 (NFALL = 40 yrs)
# Vector ISCALLOP is scallop kg/tow index, 1984-2003 (NSCALLOP = 20 yrs)
# Sigma is state equation error with parameters a0,b0
```

```
# TauFALL is autumn observation error with parameters c0FALL,d0FALL
# TauSCALLOP is scallop survey observation error
# with parameters c0SCALLOP,d0SCALLOP
#(13)##########################################################
list(
NomCatch=c(0.0671,0.0869,0.0759,0.0649,0.0396,0.0473,0.0583,0.0583,0.0715,0.264,0.2013,0.4587,0.6688,1.4454,2.2803,5.1667,6.6385,4.5562,
4.0942,4.5265,4.0689,4.6882,4.4407,4.1382,5.0545,9.1883,7.9244,10.8515,15.3362,16.6078,13.3386,16.0875,18.028,20.694,20.593,
17.849,12.96,19.45451328,11.0591012,14.38517574),
IFALL=c(5.48579,5.16263,6.98617,1.12164,0.849839,1.1379,1.35723,0.786386,4.91809,1.98611,0.710169,2.04263,1.08444,1.87322,1.39471,2.27505,1.86779,2.8583,0.645644,2.15023,0.740248,1.31789,0.551995,0.274414,0.55434,0.625257,0.425785,0.783325,0.312131,0.293588,0.610956,0.385586,0.387,0.592,0.5,0.304,0.477,0.709,1.253,0.828),
ISCALLOP=c(1.06814,1.07323,0.934246,2.41766,1.44351,1.24137,1.40098,2.21551,1.87721,2.63923,3.09495,2.09344,1.81403,1.046,0.958,2.441,2.321,1.68,1.653,2.775),
N=40,NFALL=40,NSCALLOP=20,
a0=4.0,b0=0.01,
c0FALL=2.0,d0FALL=0.01,
c0SCALLOP=2.0,d0SCALLOP=0.01,
dlowpre=0.90,
duppre=1.10,
dlowcur=0.99,
dupcur=1.01,
Bobs2001=66.23, eff=1.0, SurveyPrec2001=10.0,
Bobs2004=109.807, eff=1.0, SurveyPrec2004=1.0)
# Use a highly precise hammer to nail down trend

# Bobserved=66.23, eff=1.0, SurveyPrec=0.0228)
# Assume a CV of 10% on survey biomass to set SurveyPrec
# 0.1*66.23 = 6.623 = STDEV, PRECISION = 1/VARIANCE = 1/43.864 = 0.0326

Inits
# P[1:40] from 1964-2003
#(14)##########################################################
# Initial Condition 1
list(
P=c(0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.75,
0.75,0.75,0.5,0.5,0.5,0.4,0.4,0.4,0.3,0.3,0.3,0.2,0.2,0.2,0.2,0.2,0.2,0.2,
0.2,0.2,0.3,0.3,0.3,0.4,0.4),
Catch=c(0.0671,0.0869,0.0759,0.0649,0.0396,0.0473,0.0583,0.0583,0.0715,0.264,0.2013,0.4587,0.6688,1.4454,2.2803,5.1667,6.6385,4.5562,
4.0942,4.5265,4.0689,4.6882,4.4407,4.1382,5.0545,9.1883,7.9244,10.8515,15.3362,16.6078,13.3386,16.0875,18.028,20.694,20.593,
17.849,12.96,19.45451328,11.0591012,14.38517574),
x=1.1,
y=0.5,
K=200,
iqFALL=100,iqSCALLOP=100,
isigma2=100,
itau2FALL=100,itau2SCALLOP=100)
# Initial Condition 2
list(
P=c(0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.9,0.75,
0.75,0.75,0.5,0.5,0.5,0.4,0.4,0.4,0.3,0.3,0.3,0.2,0.2,0.2,0.2,0.2,0.2,0.2,
0.2,0.2,0.3,0.3,0.3,0.4,0.4),
Catch=c(0.0671,0.0869,0.0759,0.0649,0.0396,0.0473,0.0583,0.0583,0.0715,0.264,0.2013,0.4587,0.6688,1.4454,2.2803,5.1667,6.6385,4.5562,
4.0942,4.5265,4.0689,4.6882,4.4407,4.1382,5.0545,9.1883,7.9244,10.8515,15.3362,16.6078,13.3386,16.0875,18.028,20.694,20.593,
17.849,12.96,19.45451328,11.0591012,14.38517574),
x=1.1,
y=0.5,
K=200,
iqFALL=100,iqSCALLOP=100,
isigma2=100,
itau2FALL=100,itau2SCALLOP=100)
```